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Description

EVAPORATIVE FUEL CONTROL SYSTEM OF INTERNAL COMBUSTION ENGINE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] Pursuant to 35 U.S.C. §119 and the Paris Convention Treaty, this application claims the benefit of Japanese Patent Application No. 2003-159188, filed on June 4, 2003, and incorporated herein by reference.

BACKGROUND OF INVENTION

FIELD OF THE INVENTION

[0002] This invention relates to evaporative fuel control system of an internal combustion engine, and more particularly to an evaporative fuel control system designed to avoid degradation in exhaust gas purification performance during the detection of possible evaporative fuel control system failure.

DESCRIPTION OF RELATED ART

[0003] Traditional designs of internal combustion engines permit

for unwanted air pollution and loss of fuel due to evaporation of fuel from the tank, the carburetor, and other engine components. To obviate these problems, modern automotive vehicles typically include evaporative fuel controllers (also known as evaporative fuel control systems, evaporative emission control systems, or simply EECSs), which generally employ fuel vapor collection canisters containing an adsorbent material, such as activated carbon, for adsorbing evaporative fuel, and a purge system for releasing the adsorbed fuel and supplying it to the engine at certain times conducive to such purging.

[0004] Because EECSs rely on pressure variations to desorb the evaporative fuel adsorbed by activated carbon and to forward it to the combustion chamber of the engine, if a failure of EECS occurs, e.g., when the EECS is compromised due to a physical damage, such as a crack or hole, or due to detachment of the fuel tank cap, evaporated fuel may be emitted into the ambient atmosphere in amounts greater than if these systems were not at all present in automotive vehicles. Thus, is important to provide for a built-in detection system and methods designed to diagnose evaporative fuel control system failure whenever EECSs are used.

[0005] Evaporative fuel control system failure detection devices have been described in the literature, for example, by Tadahiro (JP Laid-Open No. H11-343925) and Shingo, et al., (JP Laid-Open No. 2000-282972). Moreover, methods for diagnosing failure of evaporative purge systems (EPSs) utilizing negative pressure in the intake pipe have been disclosed in Japanese Patents Nos. 3139095, 3139096, 3106645, and 3139188, which are owned by the assignee of this invention.

[0006] However, EECS failure detection devices described in the literature suffer from a variety of operating problems. Specifically, a change in physical conditions, such as movement of fuel in the fuel tank, temperature rise as a result of engine operation, and variations in atmospheric pressure, can affect the vapor pressure in the fuel tank and thereby degrade the precision of failure diagnosis. In addition, because EFCS failure detection devices are designed to stop checking for failure under these circumstances, if a failure coincides with the change of physical conditions failure is not timely detected resulting in prolonged air pollution and loss of fuel.

[0007] To detect a failure of EECSs, it is preferable to apply negative pressure to the system and to determine whether it

holds. However, if negative pressure is applied to the evaporative fuel control system so as to check for failure under conditions wherein the EECSs are operating normally and while much evaporative fuel resides in the evaporative system, the fuel-air mixture that is drawn into the engine becomes undesirably rich thereby resulting in incomplete combustion, rough engine operation and poor emissions. Thus there is an urgent need for EECSs and methods capable of detecting their own failure, wherein the diagnosis of failure is suspended at times when much evaporative fuel resides in the EECS detection passage.

SUMMARY OF INVENTION

[0008] The invention described herein provides an evaporative fuel control system for an internal combustion engine which system comprises an intake passage and a canister in communication with a fuel tank. The canister includes more than one chamber with an adsorbent material, such as activated carbon, provided to absorb evaporative fuel. In this system, the canister is connected to the atmosphere via an open passage which is controlled by the atmosphere open/close valve situated in the atmosphere open passage. The canister is also connected to the intake passage via a purge passage. The purge passage is con-

trolled via a purge valve situated in the purge passage. The evaporative fuel control system comprises further a purge concentration detector which detects the concentration of a purge taken into the engine and a controller which diagnoses leakage after a predetermined amount of time calculated according to the concentration of the purge detected by the purge concentration detector. The diagnosis of leakage is not performed when a high concentration of evaporative fuel resides in the passage utilized for leak diagnosis. Thus, this evaporative fuel control system and methods avoid the detrimental effect of leak detection on the exhaust gas purification performance.

[0009] In certain embodiments, this invention is directed to an evaporative fuel control system for an internal combustion engine comprising: an intake passage; a canister disposed in an evaporative fuel control passage in communication with a fuel tank to absorb the evaporative fuel; an open passage to the atmosphere to communicate said canister with the atmosphere; an atmosphere open/close valve disposed in said atmosphere open passage; a purge valve disposed between said intake passage and said canister; a detector of the concentration of purge which purge is taken into said engine; and a controller for performing a

diagnosis of failure of the evaporative fuel control system after a predetermined purge time has elapsed, said purge time being set according to the concentration of the purge detected by said detector.

[0010] In certain preferred embodiments, the predetermined purge time is set to be longer the higher the concentration of the purge. In a class of these embodiments the predetermined purge time is calculated according to the formula $Tpurge = m_1$ * (Purge Concentration) + a, wherein m_1 is a number between 0 and 50; and a is a number between -500 and 500. In a subclass of this class, m_1 is a number between 0 and 0.5, a is a number between 0 and 10, for purge concentrations lower or equal to 33.3%; m_1 is a number between 0.4 and 5 and a is a number between -100 and -50, for purge concentrations higher than 33.3% but lower or equal to 50.0%; m_1 is a number between 4 and 15 and a is a number between -400 and -300, for purge concentrations higher than 50.0% but lower or equal to 66.6%; and m_1 is a number between 0 and 0.5, and a is a number between 150 and 250, and particularly about 180, for purge concentrations higher than 66.6%,.

[0011] In certain other preferred embodiments, the controller

performs the diagnosis of failure while the atmosphere open/close valve is closed and the purge valve has been opened for a predetermined diagnosis time *T1*.

[0012] In certain other preferred embodiments, the controller prevents updating of the purge concentration value while the failure diagnosis is performed.

[0013] In certain other preferred embodiments, the predetermined diagnosis time *T1* is set based on a temperature of the fuel system and/or a value of the atmospheric pressure.

[0014] In certain other preferred embodiments, the controller is capable of diagnosing failure due to a large leak within the evaporative fuel control system, such as a large leak resultant from a detachment of a fuel tank cap.

[0015] In certain other preferred embodiments, the controller performs the diagnosis of failure of the evaporative fuel control system only when the detector detects the purge concentration which is lower than 10%.

[0016] In other aspects, the invention is directed to methods of diagnosing failure of the evaporative fuel control system by executing the following steps: (a) waiting for the predetermined purge time *Tpurge* to elapse; (b) measuring the inner tank pressure *GPT1* while the purge valve is closed

and the atmosphere open/close valve is open; (c) closing the atmosphere open/close valve; (d) opening the purge valve; (e) measuring the inner fuel tank pressure *PT* while the purge valve is open and the atmosphere open/close valve is closed; and (f) comparing said pressure measured in step (b) to said pressure measured in step (e). In certain preferred embodiments, the failure of the evaporative fuel control system is positively diagnosed when the difference between the pressure measured in step (a) and the pressure measured in step (d) is lower than a predetermined reference value *GPTL* at the time when a predetermined diagnosis time T1 has elapsed.

Brief Description of Drawings

[0017] Fig. 1 is a flowchart illustrating operation of the evaporative fuel control system of an internal combustion engine of this invention.

[0018] Fig. 2 is a flowchart illustrating a procedure for totalizing of failure diagnosis time*T1*.

[0019] Fig. 3 is a schematic diagram of the evaporative fuel control system.

[0020] Fig. 4 is a schematic diagram showing a flow of purge through the evaporative fuel control system in a normal condition.

[0021] Fig. 5 is a schematic diagram showing a flow of purge through the evaporative fuel control system in an abnormal condition in which the fuel tank cap is detached.

[0022] Fig. 6 illustrates the dependency of the initial components *Tevp* and *Tpa* of the failure diagnosis time *T1* on the temperature of fuel and the atmospheric pressure, respectively: Fig. 6(a) illustrates the relationship between temperatures of fuel/evaporative fuel control system and *Tevp* (in sec.), and Fig. 6(b) illustrates the relationship between atmospheric pressure (in kPa) and *Tpa* (in sec).

[0023] Fig. 7 is a diagram showing the relationship between the purge time *Tpurge* (in sec.) and the purge concentration (in %).

[0024] Fig. 8 is a diagram illustrating the purge concentration (in %) as a function of elapsed time (in sec.) under normal condition (solid line) and under abnormal condition, e.g., where there is a large leak, e.g., due to the fuel tank cap being detached (dashed line).

[0025] Fig. 9 is a diagram showing physical characteristics relating to the evaporative control system under a normal condition, where there is no large leak in the evaporative system: Fig. 9(a) is a time chart showing the opening angle of the purge valve (in %, wherein 0% represents a fully closed

purge value and 100% represents a fully open purge valve), Fig. 9(b) is a time chart illustrating updating of the purge concentration (in %), Figure 9(c) is a time chart showing the physical state of the atmosphere valve (showing whether open or closed), Fig. 9(d) is a time chart illustrating the totalized failure diagnosis time *T1* (in sec.), Fig. 9(e) is time chart illustrating the purge time *Tpurge* (in sec.), Fig. 9(f) is a time chart illustrating internal pressure in the intake manifold (in kPa), and Fig. 9(g) is a time chart illustrating internal pressure *PT* in the fuel tank (in kPa).

[0026] Fig. 10 is a diagram showing physical characteristics relating to the evaporative control system in an abnormal condition, where a large leak is present in the evaporative system: Fig. 10(a) is a time chart illustrating the opening angle of the purge valve (in %, wherein 0% represents a fully closed purge value and 100% represents a fully open purge valve), Fig. 10(b) is a time chart illustrating updating of the purge concentration, Fig.10(c) is a time chart showing the physical state of the atmosphere valve (showing whether open or closed), Fig. 10(d) is a time chart illustrating the totalized failure diagnosis time *T1* (in sec.), Fig. 10(e) is time chart illustrating the purge time

Tpurge (in sec.), Fig. 10(f) is a time chart illustrating internal pressure in the intake manifold (in kPa), and Fig. 10(g) is a time chart illustrating the internal pressure *PT* in the fuel tank (in kPa).

[0027] Fig. 11 is a diagram illustrating physical characteristics relating to the evaporative control system before, during, and after recovery from an abnormal condition to the normal condition: Fig. 11(a) is a time chart illustrating the opening angle of the purge valve (in %, wherein 0% represents a fully closed purge value and 100% represents a fully open purge valve), Fig. 11(b) is a time chart illustrating the engine speed (in rpm), Fig. 11(c) is a time chart illustrating fuel correction value based on the purge concentration (in %), Fig. 11(d) is a time chart showing the physical state of the atmosphere valve (showing whether open or closed), and Fig. 11(e) is a time chart illustrating the inner tank pressure *PT* (in kPa).

[0028] Fig. 12 is a diagram illustrating physical characteristics relating to the evaporative control system of prior art before, during, and after recovery from an abnormal condition to a normal condition: Fig. 12(a) is a time chart illustrating the opening angle of the purge valve (in %, wherein 0% represents a fully closed purge value and 100% repre-

sents a fully open purge valve), Fig. 12(b) is a time chart illustrating engine speed (in rpm), Fig. 12(c) is a time chart illustrating fuel correction value based on the purge concentration (in %), Fig. 12(d) is a time chart showing the physical state of the atmosphere valve (showing whether open or closed), and Fig. 12(e) is a time chart illustrating the inner tank pressurePT (in kPa).

DETAILED DESCRIPTION

[0029] The invention disclosed herein will be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein, rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

[0030] Many modifications and other embodiments of the invention will come to mind to one skilled in the art to which this invention pertains having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the

invention is not to be limited to the specific embodiments disclosed herein and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

ARCHITECHTURE

[0031] The architecture of an evaporative fuel control system of this invention will now be described in more detail. Fig. 3 is a schematic diagram showing an internal combustion engine 2(also referred to as "engine"), having one or more combustion chambers (not shown); an intake pipe *4*, comprised of a surge tank *6*, an intake passage (also referred to as intake manifold)*8*, and a throttle valve *10*; a fuel tank *12*, having a fuel tank cap *12-1*; and an evaporative fuel control system*14*. Within the evaporative fuel control system*14*, an evaporative fuel control passage *16* connects the fuel tank *12* to the surge tank *6* downstream (i.e., on the side of the surge tank located closer to the engine combustion chamber) of the throttle valve *10*. A canister *18* is located in the evaporative fuel control passage *16* so as to adsorb the evaporative fuel. The evaporative fuel control passage *16* is further comprised of an evaporation

passage *20* which connects the fuel tank *12* and the canister *18*, and a purge passage *22* which connects the canister*18* and the surge tank *6*. The canister *18* includes more than one chamber containing an adsorbent material, such as activated carbon. Within the purge passage *22*, a purge valve *24* is situated to regulate the amount of evaporative fuel purged from the canister *18* and supplied to the intake passage *8*. The canister *18* is further connected to one end of an atmosphere open passage *26.* The other end of the atmosphere open passage *26* connectsto the ambient atmosphere via an atmosphere open/close valve *28*.

[0032] The purge valve *24* and the atmosphere open/close valve *28* are connected to a controller (e.g, a microprocessor-based engine management computer, ECM, or power control module, PCM) *30*. Controller *30* is also connected to an inner pressure sensor *32*, a fuel level sensor *34*, and a purge concentration detector *36*. More particularly, the inner pressure sensor *32* is attached to the fuel tank *12* to detect the inner pressure within the fuel tank *12*. The fuel level sensor *34* is situated in the fuel tank *12* to detect the fuel level in the fuel tank *12*. The purge concentration detector *36* is situated within the purge passage *22,* and more particularlybetween the canister *18* and the purge

valve *24*, to detect the concentration of fuel in the purge gas taken into the internal combustion engine *2* (purge concentration).

[0033] The controller *30* detects EECS failure of the evaporative system as defined by the boundaries of the fuel tank *12*, the purge valve *24*, and the atmosphere valve *28*, by means of the negative pressure of the engine *2*. Specifically, the controller *30* includes a failure detecting section *30-1* for detection of an abnormal condition (e.g., large leakage of evaporative fuel), and a timer *30-2*.

OPERATION

[0034] EECS failure diagnosis performed while much evaporative fuel resides within the evaporative fuel control passage (i.e., when the concentration of evaporative fuel in the evaporative fuel control passage exceeds about 30%) results in incomplete combustion, rough engine operation and poor emissions. Thus, the controller *30* is configured to perform EECS failure diagnosis only after a purge has been carried out for a predetermined time *Tpurge*, which is calculated according to the purge concentration measured by the detector *36*. Purge concentration refers to the concentration of vaporized fuel within the air fuel mixture purged into the intake passage *8* during purge cycles.

[0035] The predetermined time $Tpurge$ is greater the higher the concentration of the purge. That is, the time of purge becomes longer the higher the concentration of the fuel in the purge, and the time of purge becomes shorter the lower the concentration of the fuel in the purge. The predetermined purge time $Tpurge$ is set based on the purge concentration as shown in Fig. 7. Specifically, the totalized purge time $Tpurge$ (in sec.) is calculated according to the formula $Tpurge = m_1$ * (Purge Concentration) + a, wherein m_1 is a number between 0 and 50 and a is a number between -500 and 500. For purge concentrations lower or equal to 33.3%, m_1 is particularly between 0 and 0.5 and a is a number between 0 and 50, and more particularly a is a number between 0 and 10; for purge concentrations higher than 33.3% but lower or equal to 50.0%, m_1 is particularly between 0.4 and 5 and a is a number between -100 and -20, and more particularly a is a number between -100 and -50; for purge concentrations higher than 50.0% but lower or equal to 66.6%, m_1 is particularly between 4 and 15 and a is a number between -500 and -200, and more particularly a is a number between -400 and -300; and for purge concentrations higher than 66.6%, m_1 is particularly between 0 and 0.5, and a is par-

ticularly between 150 and 250, and more particularly about 180.

[0036] The success of the diagnosis of failure is predicated upon the proper operation of the atmosphere open/close valve *28*. Thus, before completing EECS failure diagnosis the proper operation of the atmosphere open/close valve is checked according to the following procedure. The inner tank pressure *PT* (kPa) is measured by the inner pressure sensor *32* while the purge valve *24* is closed (at an opening angle of 0%; purge-off) and while the atmosphere open/close valve *28* is open. This measured pressure is referred to as the inner tank pressure *GPT1* (purge-off). At this time, because the atmosphere open/close valve is set to open, the pressure in the evaporative system is supposed to equal to that of the atmosphere, except if the atmosphere open/close valve *28* is in failure. Therefore, it is determined that the atmosphere open/close valve *28* is in failure if the inner tank pressure *GPT1* (purge-off) is higher than a certain high pressure threshold *PThigh* for determination of failure of the atmosphere valve *28*, or is lower than a certain low pressure threshold *PTlow* for determination of failure of the atmosphere valve *28*. Specifically, in certain embodiments of this invention, *PThigh* is a

pressure between about 90 kPa and about 120 kPa and *PT-low* is a pressure between about 50 kPa and about 110 kPa.

[0037] If it is determined that the atmosphere valve *28* is not in failure, then the atmosphere valve *28* is closed and the purge valve *24* is opened. After the purge valve *24* has been opened for a predetermined amount of time *T1*, the controller *30* performs additional steps in the diagnosis of failure.

[0038] Since during the diagnosis of EECS failure the concentration of purge is different from that present during normal system operation, during EECS failure diagnosis the controller *30* prevents the purge concentration value stored in the controller from being updated. This is to say that during certain parts of the EECS failure diagnosis, the controller *30* does not register new values of purge concentration as measured by the purge concentration detector in the controller"s memory for the purpose of EECS failure diagnosis. After the diagnosis of a normal condition, i.e., the absence of failure, however, the controller restarts updating the purge concentration with the last value stored in the memory.

[0039] In certain embodiments of this invention, the diagnosis of

EECS failure is based on comparison of the inner tank pressure *PT* (in kPa), the inner tank pressure *GPT1* during the purge-off (in kPa) and a reference value *GPTL* within the diagnosis time *T1*. In certain embodiments of this invention, the reference value *GPTL* is a number between -0.4 and -0.9 kPa, more particularly between -0.5 and -0.8 kPa and most particularly about -0.7 kPa ≈ - 5 mmHg. Specifically, it is determined that the evaporative system is in the normal condition if a difference between the inner tank pressure *PT* (kPa) of the closed evaporative system and the inner tank pressure *GPT1* during purge-off is greater than or equal to a reference value *GPTL* within the diagnosis time *T1*. Thus, it is determined that the evaporative system is in the normal operating condition if the equation $(GPT1 - PT) \geq GPTL$ is satisfied. Conversely, it is determined that the EECS is in failure if within the diagnosis time *T1* the equation $(GPT1 - PT) \geq GPTL$ is not satisfied.

[0040] In certain other embodiments of this invention, the normal operating condition, i.e., the lack of failure, may be determined by comparing the tank inner pressure *PT* directly to the reference value *GPTL*. Specifically, normal operating condition is present when the tank inner pressure

PT is greater or equal to the reference value $GPTL$ within the diagnosis time $T1$, or whenthe equation $PT \geq GPTL$ is satisfied. Conversely, EECS failure is present when the tank inner pressure PT is lower than reference value $GPTL$ within the diagnosis time $T1$,or whenthe equation $PT \geq GPTL$ is not satisfied.

[0041] Following the diagnosis of normal operating conditions (as opposed to EECS failure) within the diagnosis time $T1$, the purge valve *24* is returned to its open position for ordinary EECS operation.

[0042] During the diagnosis of failure it may become of importance that at higher operating temperatures, higher operating altitudes and at lower atmospheric pressures, more fuel vapors are generated in the fuel tank 12than at lower operating temperatures, lower operating altitudes and higher barometric pressures. Specifically, under the former conditions the high pressure of evaporated fuel in the EECS may adversely affect the diagnosis of failure of the EECS and may result in a false positive failure determination. Accordingly, certain embodiments of this invention provide for initial setting of the diagnosis time $T1$ based on the temperature of the fuel system and/or the atmospheric pressure. Specifically, in certain embodiments of

this invention, the diagnosis time *T1* is initially calculated from the equation: $T1 = Tevp + Tpa$. That is to say that the diagnosis time *T1* is initially calculated only based on *Tevp* and *Tpa*. However, when purge concentrations are higher at the time of failure determination, the time *T1* is extended by the controller (i.e., totalized) until the high purge concentrations subside.

[0043] As shown in Figure 6(a), time *Tevp* (sec.) is determined based on the fuel temperature (fuel system temperature) and/or the evaporative system temperature. In certain embodiments, the fuel temperature and the evaporative system temperature are measured directly by temperature sensors placed in the fuel tank and within the evaporative emission control system, respectively. In other embodiments, fuel temperature and the evaporative system temperature are determined indirectly from appropriate data value tables, e.g., tables relating the fuel temperature and/or the evaporative system temperature to other physical characteristics of the system.

[0044] Specifically, $Tevp = m_2$ * (Temperature of fuel) + b, wherein at temperatures lower than 30°C, $m_2 = 0$ and b is an amount of time between 0 and 20 seconds, more particularly between 1 and 10 seconds, and most particularly

about 5 sec.; and wherein at temperatures greater or equal to 30°C, m_2 is a number between 0 and 5, more particularly between 0.05 and 2, and most particularly about 0.375, and b is a number between -20 and 20, more particularly between -10 and 10, and most particularly about -6.25.

[0045] The "temperature of fuel" in the above equation for the determination of $Tevp$ represents the actual fuel temperature in the fuel tank, as measured by a temperature sensor, or as determined from other physical characteristics of the system; or it represents the temperature of the evaporative emission system, as measured by a temperature sensor, or as determined from other physical characteristics of the system; or it represents a combination of the actual fuel temperature in the fuel tank and the temperature of the evaporative emission system, e.g, as their average, simple, weighted, or otherwise; or it represents any other value directly or indirectly related to the actual fuel temperature in the fuel tank or the temperature of the evaporative emission control system, or to both.

[0046] As shown in Figure 6(b), time Tpa (in sec.) is determined based on the atmospheric pressure (in kPa). Specifically, Tpa = m_3 * (Atmospheric pressure) + b, wherein m_3 is a

number between -5 and -0.01, more particularly between -0.5 and -0.01, and most particularly about -0.111, and *b* is a number between 0 and 20, more particularly between 5 and 15, and most particularly about 10.

[0047] Under normal conditions where no leak occurs in the evaporative system, as shown in Fig. 4, the ambient air drawn through the atmosphere open/close valve *28* passes through the cylinder *18* where it picks up desorbed fuel continuing through the purge valve *24* to the intake passage *8* of the engine. The concentration of fuel in the purge decreases with time as evaporated fuel is drawn into the engine. This is illustrated by the solid purge concentration line in Fig. 8. However, if the fuel tank cap *12-1* is detached, a condition shown in Fig. 5, the ambient air is additionally drawn through the fuel tank opening created by the absence of the fuel tank cap. Accordingly, under these conditions, the concentration of the fuel in the purge does not decrease with time, as shown by the dashed line in Fig. 8, because the ambient air passing through the fuel tank continuously picks up new fuel vapors and carries them through cylinder *18* and the purge valve *24* to the intake passage *8* of the engine. When the fuel tank cap is replaced the abnormal condition illus-

trated in Fig. 5 reverts to the normal condition shown in Fig. 4 and the amount of fuel vapors generated in the fuel tank decreases rapidly.

[0048] EECSs described in the literature suffer from the following problem: at the instant the EECS is restored from failure to a normal operating condition (e.g., when a fuel tank cap is replaced), the fuel supplied to the engine is corrected based still on the previously measured purge concentration, which was necessarily large due to existing failure. However, because the EECS failure is no longer present at that time, the content of fuel in the fuel air mixture is overcorrected and becomes lean, which results in bad drivability due to engine speed decrease or engine stall, as shown in Fig. 12. To obviate this problem, certain embodiments of this invention provide for clearing of the previously measured purge concentration from the memory and for remeasuring it during the detection of EECS failure (step *128*, Fig. 1). This procedure corrects the problems of lean fuel to air mixture and results in normal drivability, as illustrated in Fig. 11.

[0049] Referring to Fig. 1, the program for control of the evaporative fuel control system14will now be described in detail. The control program starts in step *100.* A determina-

tion is made in step *102* whether the purge concentration measured by the purge concentration detector*36* has been updated, i.e., the program waits for a new purge concentration measurement data to arrive at the controller *30*. If this is not the case, step *102* is repeated. If, however, the purge concentration has been updated, a determination is made in step *104* whether the elapsed time since the purge has started exceeds the purge time *Tpurge*. If this is not the case, steps102and*104* are repeated. If the elapsed time since the purge has started exceeds the purge time *Tpurge*, however, the tank inner pressure *GPT1* is measured while the purge is not performed, i.e., while the purge valve *24* is shut off, and while the atmosphere open/close valve *28* is open. Then the determination is made in step *108* whether the tank inner pressure *GPT1* is less than the threshold *PThigh*. If this is not the case then the atmosphere open/close valve *28* has likely failed (step *112*), as the pressure in an open to atmosphere system would not likely exceed the value of*PTHigh*. If, however the tank inner pressure *GPT1* is less than the threshold *PThigh*, then while the purge valve*24* is still shut off and the atmosphere open/close valve *28* is still open, a determination is made in step *110* whether the tank inner pressure *GPT1* is greater

than the threshold *PTlow*.If this is not the case then the atmosphere open/close valve *28* has likely failed (*step 112*), as the pressure in an open to atmosphere system would not likely be below the value of *PTlow*. If *GPT1* is greater than the low threshold *PTlow*, the atmosphere open/close valve *28* is closed in step *114*, and while the controller *30* prevents the purge concentration from being updated, the purge valve *24* is opened in step *116*. Following the purge valve opening, a determination is made in step *118* whether the difference between the inner tank pressure *PT* of the closed evaporative system and the inner tank pressure *GPT1* recorded during purge-off is greater than or equal to a reference value *GPTL* within the diagnosis time *T1*. This is represented by the equation: $(GPT1 - PT) \geq GPTL$. If this is the case, then the atmosphere open/close valve *28* is opened in step *120*, and it is determined in step *122* that the EECS is in a normal condition. If, however, the equation: $(GPT1 - PT) \geq$GPTLis not satisfied,then adetermination is made in step *124* whether the diagnosis time *T1* has elapsed. If the diagnosis time *T1* has not elapsed then the program returns to step *118*. If, however, the diagnosis time *T1* has elapsed then the atmosphere open/close valve *28* is opened in step *126*. The concentration of purge

is cleared and remeasured in step *128*, and it is determined that the system is in failure in step *130*.

[0050] Referring to Fig. 2, the control program for totalizing the large leak diagnosis time *T1* will now be described in more detail. The control program for starts in step *200*. A determination is made in step *202* whether the purge concentration is grater than 10%. If this is not the case then the failure diagnosis time *T1* is not totalized and the program repeats step *202*. If, however, the purge concentration exceeds 10% then a determination is made in step *204* whether the negative pressure in the intake manifold is lower than300 mmHg. If the negative pressure in the intake manifold is not less than -300 mmHg then the program returns to step *202*. If, however, the negative pressure in the intake manifold is less than -300 mmHg, then *T1* is totalized is step *206* and the program returns to step *202*. This is to say that the *T1* time is continuously extended by the controller until such time when the purge concentration is less than or equal to 10% and the negative pressure in the intake manifold is greater than or equal to -300 mmHg. Thus, the controller *30* performs failure diagnosis after the predetermined time *T1* set according to the concentration of the purge detected by the

purge concentration detector *36*, and the diagnosis for the leakage is not performed when much evaporative fuel resides in the passage for failure diagnosis. This avoids affection to the exhaust gas purification performance during the detection of possible failure.

[0051] Also, the predetermined time *Tpurge* is set according to the purge concentration detected by the purge concentration detector *36*. The predetermined time is set to be longer as the concentration of the purge becomes higher. That is, the controller *30* waits for a longer amount of time before starting failure diagnosis so that the high purge concentrations may subside. This avoids the degradation in exhaust gas purification performance during the detection of possible evaporative fuel control system failure.

[0052] In summary, some of the advantages of the various embodiments of this invention are as follows. Because the controller *30* performs failure diagnosis while the atmosphere open/close valve *28* is closed and the purge valve *24* is opened for the predetermined diagnosis time *T1*, the need for an additional sensor or control system is eliminated. In addition, the controller *30* prevents updating of the purge concentration value during failure diagnosis because the concentration of the purge during diagnosis of

failure is different from that under normal EECS operation. This avoids the problem of bad drivability after an abnormal condition is diagnosed. Also the diagnosis time *T1* is initially set based on the temperature of the fuel system or the atmospheric pressure, which parameters affects the amount of the evaporative fuel generated within the system. This greatly improves the precision of the failure diagnosis and is advantageous in practical use.

[0053] This invention is not to be limited to the specific embodiments disclosed herein and modifications for various applications and other embodiments are intended to be included within the scope of the appended claims. For example, in the aforementioned embodiments, the function to determine the abnormal condition (large leakage due to e.g., puncture, corrosion, loss of seal, etc.) is included within the EECS control flow. However, an abnormal condition, such as that presented when the fuel tank cap is detached may be detected within the realm of another system. More particularly, in certain embodiments of this invention, a detector is placed directly in communication with the fuel tank cap and when the fuel tank cap is removed the detector, having detected the removal, communicates said removal by causing a visual signal to be

displayed and/or an audio signal (e.g., buzzer) to be rung inside the vehicle. Thereby, the detachment of the cap from the fuel tank can be easily detected with reliability, which is advantageous in practical use. In yet other embodiments, this invention provides for a detector disposed at various pipe junctions of the evaporative passage or the purge passage so as to monitor for abnormal leakage condition and to attribute the abnormal condition to poor pipe connections. Therefore, while this invention has been described in connection with particular examples thereof, the true scope of the invention should not be so limited since other modifications will become apparent to the skilled practitioner upon a study of the drawings, specification, and following claims.